Stationkeeping about Apophis through its 2029 Earth Flyby. D.J. Scheeres, A. Meyer and A.B. Davis, Smead Department of Aerospace Engineering Sciences, University of Colorado Boulder <scheeres@colorado.edu>.

Abstract: The dynamics and control of a satellite in orbit about the asteroid Apophis through its Earth close approach in 2029 is evaluated and investigated. First, the feasibility of carrying out close proximity operations about Apophis when in its heliocentric orbit phase is evaluated and shown to be feasible. Then three different types of close proximity motion relative to Apophis are analyzed that will enable a spacecraft to take observations throughout the Earth close approach. These are maintaining a relative orbit that is somewhat distant from Apophis, hovering along the Earth-Apophis line, or maintaining orbit about Apophis through the flyby. Each of these are shown to be feasible, albeit challenging, and some basic aspects of these operations are noted and discussed.

Introduction: The 2029 flyby of Earth by the asteroid (99942) Apophis will be a spectacle for all humanity to observe. The asteroid will be close enough to the Earth to be visible during its close approach, at approximately 37,200 km from the center of the Earth (under 6 Earth radii). A number of proposed missions are in development for taking advantage of its close Earth passage in order to measure what effects the strong Earth tidal forces may have as it passes through closest approach [1, 2, 3]. These concepts include having both landed and orbital elements about this small asteroid. Previous analyses have shown that the surface forces and changes will be modest, even though the rotation state will change significantly, and thus that landed elements may be feasible [4, 5, 6]. This paper will instead consider the relative dynamics of any co-orbiting vehicles about Apophis during its close approach to Earth, in order to evaluate if it will be feasible to both stay in close proximity to the asteroid during the Earth closest approach, and what level of control effort may be required to enable spacecraft relative observations through the entire close approach passage. Previous analysis has looked at the feasibility of orbiting about Apophis [1,2], however they have not considered the feasibility of maintaining orbit or proximity through the closest approach to Earth. This analysis uses the recently measured Apophis shape and spin state based on radar measurements [8].

This analysis will look at a number of different approaches for maintaining proximity through the Earth flyby. These include having a spacecraft in the vicinity of the asteroid (but not in orbit about it), a spacecraft in orbit about the asteroid, and a spacecraft actively hovering in close proximity to the asteroid. For some of the proposed scientific investigations it will be crucial that a spacecraft in proximity observe the asteroid throughout the entire closest approach phase. The challenge is that the spacecraft will be perturbed by the relative dynamics induced by the flyby, which has a closest approach of 37,200 km and a hyperbolic eccentricity of 4.232. Thus there may be challenges to maintaining a useful relative orientation to the body. By studying the effects of the flyby on different relative orbits it will be possible to better design any candidate mission to this body.

The talk is structured as follows. First we review the model of Apophis, including its spin state and shape in addition to its orbital characteristics. Next we introduce the different approaches for maintaining observation of Apophis before, during and after the closes approach. We study the placement of a spacecraft in orbit about Apophis and in a neighboring heliocentric orbit in particular, showing that both of these approaches are feasible. Finally, we discuss the implications of our results and state our conclusions.

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